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Applicant:	Behrang Behin et al.
Application Title:	MEMS MIRRORS WITH PRECISION CLAMPING MECHANISM
Examiner:	Not Yet Assigned
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PRELIMINARY AMENDMENT

Commissioner of Patents and Trademarks
Washington, DC 20231

Sir:

Prior to examination of the above application, kindly amend the application as follows:

TITLE:

Kindly amend the title of the application to read "USE OF APPLIED FORCE TO IMPROVE MEMS SWITCH PERFORMANCE" as shown on amended page 1.

CLAIMS:

Cancel claims **1-25**, amend claim **26** and enter new claims **27-37** as shown on the replacement claims pages below. The details of the amendment to claim **26** are described in the "Claim Amendments" section below.

SPECIFICATION

Kindly amend the specification by replacing pages 1, 2, and 21, with amended pages 1, 2, and 21, which are reproduced below. The details of the amendments to the specification are described in the "Specification Amendments" section below.

REPLACEMENT CLAIMS

26. A method for operating a MEMS device having a flap that is movable with respect to a base, the method comprising: applying a pre-bias force to the flap to move the flap at least partially out of contact with an underlying base.

27. The method of claim 26, wherein the force produces a biasing torque on the flap to reduce stiction and improve reliability.

28. The method of claim 26, wherein the force produces a biasing torque on the flap to increase switch reliability.

29. The method of claim 26 wherein the force is applied by a biasing element chosen from the group consisting of a fixed magnet, current carrying coils, flap torsion springs, magnetic materials, gap-closing electrodes, spring loaded elements, stress bearing materials, piezoelectric elements and thermal bimorph actuators.

30. The method of claim 26 wherein the force produces a biasing torque on the flap.

31. The method of claim 30 wherein the biasing torque tends to counteract another torque exerted on the flap.

32. A microelectromechanical apparatus comprising:
a base;
a flap having a portion coupled to the base so that the flap is movable out of the plane of the base from a first angular orientation to a second angular orientation;
wherein the base has an opening that receives the flap when the flap is in the second angular orientation, the opening having one or more sidewalls, wherein at least one of the sidewalls contacts a portion of the flap such that the flap assumes an orientation substantially

REPLACEMENT CLAIMS

parallel to that of the sidewall when the flap is in the second angular orientation;

a sidewall electrode disposed in one or more of the sidewalls and

means for applying a pre-bias force to the flap to move the flap at least partially out of contact with an underlying base.

33. The apparatus of claim 32 wherein the means for applying a force applies a fixed force to the flap.

34. The apparatus of claim 32 wherein the means for applying a force is a biasing element chosen from the group consisting of flap torsion springs, magnetic materials, current carrying coils, gap-closing electrodes, spring loaded elements, stress bearing materials, piezoelectric elements and thermal bimorph actuators.

35. The apparatus of claim 32 wherein the means for applying a force produces a biasing torque on the flap.

36. The apparatus of claim 35 wherein the biasing torque tends to counteract another torque exerted on the flap.

37. The apparatus of claims 32 where the base is made from a substrate portion of an SOI (silicon-on-insulator) wafer and the flap is defined from a device layer portion of the SOI wafer.

AMENDED PAGE 1

Patent Application of

Behrang Behin, Michael J. Daneman, Chuang-Chia Lin, Boris Kobrin, Murali Chaparala

for

USE OF APPLIED FORCE TO IMPROVE MEMS SWITCH PERFORMANCE

CROSS-REFERENCE TO RELATED APPLICATION

This application is a divisional of Application Serial No. 09/834,744, which is based on and claims priority from Provisional application 60/250,081 filed November 29, 2000, both of which are incorporated herein by reference.

FIELD OF THE INVENTION

This invention relates generally to microelectromechanical structures (MEMS). More particularly, it relates to a clamping mechanism for MEMS apparatus.

BACKGROUND OF THE INVENTION

MEMS free-space optical switches can be categorized into two major branches: the planar matrix (2-dimensional) approach, and the beam-steering (3-dimensional) approach. The 2D approach typically involves mirrors that move between on and off position. The angular accuracy at the on position is extremely critical as it affects the alignment of the mirror and optical loss of the switch.

Using <110> silicon with anisotropic etchants, one can form trenches with 90-degree sidewalls. If one bonds this wafer to another wafer that has free rotating mirrors, the sidewall can serve as a reference stopping plane to fix the up- mirrors in a vertical position. In addition, the sidewall may also serve as an electrode for electrostatically clamping the mirror in the vertical position.

One type of optical switch employs microelectromechanically-actuated mirrors. Fig. **1** depicts one type of MEMS actuated

switch **100** that is made using 2 substrates. A top chip **101** containing a sidewall for receiving a movable mirror **111** is bonded to a bottom chip **102** containing a base **103**. There are a few complications associated with the two-wafer approach. The attachment process requires a very high accuracy aligner-bonder. Moreover, the two-chip process places certain geometrical constraints that limit the minimum geometry of the trenches and mirrors. Furthermore, the complexity of the fabrication and alignment process can increase cost and reduce yield. In addition, stiction or squeeze-film damping between the movable mirror **111** and the base **103** may adversely affect the performance of the switch **100**.

Therefore, there is a need in the art for a low-cost, high-yield, high performance, reliable, scalable switch and a process of fabricating same.

SUMMARY OF THE INVENTION

The disadvantages associated with the prior art may be overcome by a method for operating a MEMS device having a flap that is movable with respect to a base. The method includes applying a force to the flap to move the flap at least partially out of contact with an underlying base. Means for applying such a biasing force may be incorporated into a microelectromechanical (MEMS) apparatus having a base and a flap with a bottom portion coupled to the base so that the flap may move out of the plane of the base between first and second angular orientations. An array of one or more of such structures may be used to form an optical switch. The base may have an opening with largely vertical sidewalls containing one or more electrodes. The sidewalls contact a portion of the flap when the flap is in the second angular orientation. The electrodes may be electrically isolated from the base. The flap may include a magnetic material so that the flap moves in response to an external magnetic field. A voltage source may be coupled between the flap and the sidewall electrode to apply an electrostatic force between the sidewall electrode and the flap such that the flap assumes the angular orientation of the sidewall. The electrostatic force may be sufficient to prevent the flap from changing position in the presence of an applied magnetic field. The apparatus may further include an electrode on the base and a voltage

REDUCING STICTION IN A MEMS DEVICE WITH AN APPLIED FORCE

ABSTRACT OF THE DISCLOSURE

A method is disclosed for operating a MEMS device having a flap that is movable with respect to a base. The method includes applying a force to the flap to move the flap at least partially out of contact with an underlying base. Means for applying such a biasing force may be incorporated into a microelectromechanical (MEMS) apparatus having a base and a flap with a portion coupled to the base so that the flap may move out of the plane of the base between first and second position. The base may have a cavity with largely vertical sidewalls that contact a portion of the flap when the flap is in the second position Electrodes may be placed on the vertical sidewalls and electrically isolated from the base to provide electrostatic clamping of the flap to the sidewall. The base may be made from a substrate portion of a silicon-on-insulator (SOI) wafer and the flap defined from a device layer of the SOI wafer. The flap may be connected to the base by one or more flexures such as torsional beams. An array of one or more of such structures may be used to form an optical switch.

Claim Amendments

Claim 26 has been amended as follows:

26. (AMENDED) A method for **[reducing stiction in a]** operating a MEMS device having a flap that is movable with respect to a base, the method comprising:
applying a **[fixed]** pre-bias force to the flap to move the flap at least partially out of contact with an underlying base.

New Claims

New claims 27-31 cover material that was disclosed in the original specification at page 8, lines 1-25, Figs. 2A-2B, 6 and original claim 26. The applicants submit that no new matter has been added with this amendment.

Specification Amendments:

The applicants respectfully request that the following amendments have be entered with respect to the original specification:

At page 1, line 5, change "MEMS MIRRORS WITH PRECISION CLAMPING MECHANISM" to -- USE OF APPLIED FORCE TO IMPROVE MEMS SWITCH PERFORMANCE --;

at page 1, line 8, after "This application", insert -- is a divisional of Application Serial No. 09/834,744, which --;

at page 1, line 9, after "November 29, 2000" Insert --, both of which are incorporated herein by reference --;

at page 2, line 10, after "yield." Insert --In addition, stiction between the movable mirror **111** and the base **103** may adversely affect the performance of the switch **100**.--;

at page 2, line 13, after "yield" and before "scalable" insert --, low-stiction,--;

at page 2, line 17, after "overcome by a" and before "microelectromechanical" insert -- method for reducing

stiction in a MEMS device having a flap that is movable with respect to a base. The method includes applying a force to the flap to move the flap at least partially out of contact with an underlying base. Means for applying such a biasing force may be incorporated into a --;

at page 21 line 5, after "A" and before "microelectromechanical" insert --method is disclosed for reducing stiction in a MEMS device having a flap that is movable with respect to a base. The method includes applying a force to the flap to move the flap at least partially out of contact with an underlying base. Means for applying such a biasing force may be incorporated into a --;

at page 21, line 5, after "apparatus", change "has" to --having--;

REMARKS:

Reasons This Amendment Should be Entered

The Applicants submit that the amendments submitted herein are being made with the filing of the application. The Applicants respectfully request entry of the amendment to correct minor informalities and to cover material within the scope of the present invention.

Title Amendment

The title has been amended to reflect the scope of claims 26-37.

Specification Amendments

The Applicants have amended the specification to include a cross reference to the parent application (U.S. Ser. No.

09/834,744) and to make the summary and abstract correspond to the claims. Support for these amendments can be found in the specification, e.g., at page, 8, lines 1-25, Figs. 2A-2B and 6. The applicants submit that these amendments merely make explicit that which was implicit in the original specification as filed. As such, no new matter has been added with these amendments.

Claim Amendments

The Applicants have amended claim 26, which is directed to a method for reducing stiction, and added new claims 27-37 to cover material, which they believe to be inventive, and disclosed in the parent application. The applicants submit that no new matter has been added with these amendments. Claim 26 has been amended to replace "fixed" with --pre-bias--. Support for this amendment can be found in the specification at page 8, lines 1-4. The applicants submit that the amendment does not narrow, and indeed broadens, the scope of claim 26. As such this amendment does not narrow the scope of claim 26 within the meaning of the decision in *Festo Corp. v. Shoketsu Kogyo Kabushiki Co., Ltd., 234 F3d 558, 566, 56 U.S.P.Q.2d 1865 (Fed. Cir. 2000)*.

New dependent claims 27-31 cover features in addition to those claimed in claim 26. Support for claims 27-31 may be found in the specification at page 8, lines 1-25.

New dependent claims 32-37 are directed to apparatus that incorporate similar features to those described in claim 26-31. Support for these claims can be found in the specification at page 8, lines 1-25, and Fig. 2A-2B.

CONCLUSION

The Applicants respectfully request entry of the amendment prior to consideration of the application and that the Examiner consider the application and point out the allowable material in the next office action.

Respectfully submitted,

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Date: 8/18/2021

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